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Application of CCME water quality index for drinking purpose in Tigris River within Wasit Province, Iraq

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ABSTRACT

The water quality index (WQI) is an essential part of the water resource management system through its use as a numerical scale to evaluate and classify the quality of the water body for various beneficial uses (drinks, industry and irrigation).The present study used WQI based on the Canadian Council of Ministers of the Environment (CCME-WQI) as a tool for assessing the quality of Tigris River in Wasit Province, Iraq for drinking purposes through assaying different chemical and physical parameters. Four sites were selected along the river between Al-Kut City and Al-Aziziyah from August 2016 through July 2017. Water samples were collected monthly and nine physicochemical parameters were selected: pH, dissolved oxygen, nitrate, phosphate, sulfate, chlorides, lead, zinc and manganese. Based on the results of water quality index, the river water was considered as marginal in all the studied sites, and the CCME-WQI ranged between 56-62. The highest deviation has been occurred in phosphate, nitrate, sulfate, lead, and manganese, leading to decrease the water quality index value.

Keywords: CCME water quality index, Drinking purposes, Tigris River.

Article type: Research Article.

INTRODUCTION

Rivers are the most important freshwater resources for human uses. So far as the health of river in Iraq is concerned, river pollution rapidly increases due to industrial, agricultural and human activities. Almost every aspect of hydrological cycle of rivers led to river pollution. There are several studies about water quality around the world (Rafiee *et al.* 2019; Khatun & Rashidul Alam 2020; Zidani *et al.* 2020; Benfridja *et al.* 2021; Fallah *et al.* 2021; Omidi & Shariati 2021; Abdouni *et al.* 2021) Referring to the water quality required for human uses (such as drinking, agricultural and industrial purposes), WQ is important to preserve human health and river health. Water quality management involves routine monitoring in order to detect changes in water over time, and the Iraqi -WQI was constructed to be used to assess the Iraqi rivers for drinking purposes (Ewaid *et al.* 2020). Mechanical, chemical and biological properties have been used to track the degradation of water quality. Some factors generally refer to water pollution, while others directly refer to water pollution sources (UNEP / GEMS 2005). Therefore, monitoring the quality of water is a useful approach for determining that the regulated water is sufficient for the use and living aquatic life needed (UNEP/WHO 1996). The CCME-WQI was used as an instrument to promote the assessment of water quality for different uses. This study is an attempt to assess the suitability of Tigris River at Wasit Province for drinking purposes through using the Canadian water quality index.

MATERIALS AND METHODS

Study Area

Four sites were chosen along Tigris River in Wasit Province, as shown in Fig. 1 and Table 1. The province is located about 180 km south of Baghdad and its area is 17153 km^2. The province is distinguished by agriculture.

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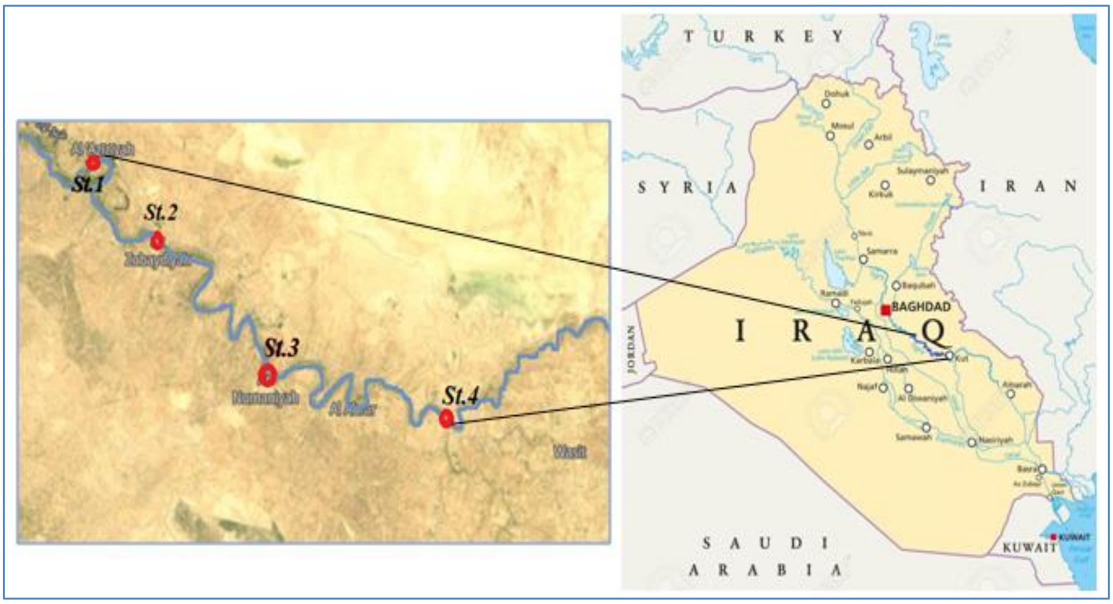

Fig. 1. The study area (Used Arc-GIS Map program).

Table 1. The geographical positions (GPS) of the four studied sites.

Sites	Longitude (eastwards)	Latitudes (northward)
S1: Al-Aziziyah	38º.1835′	54º.9050′
S2: Zubaidiyah	35º.9799′	55º.8840′
S3: Numaniyah	35º.9611′	57º.7080′
S4: Kut dam	36º.1336′	60º.5320′

Sampling

The water samples were collected monthly from the study area from August 2016 to July 2017 and were analyzed for physicochemical parameters in the Laboratory of Biology Department, College of Science, Tikrit University, Iraq. Four sites were selected at Tigris River, Wasit Province including Al-Aziziyah, Zubaidiyah and Numaniyah, Kut dam, as shown in Table 1.

Water analysis

Measurement of pH

The pH of water samples in the field were directly measured using a multi digital mobile device i.e., Portable Digital pH Meter after calibration by standard intravenously buffer solution with values of 4.7 9.

Dissolved Oxygen (DO)

The Azide Modification of the Winkler Method were used to determine the DO concentration in the water (Marckerath 1963), where the bottles of oxygen-volume (250 mL) was immersed in the water and filled with it. After making sure that there are no air bubble, the device was installed to measure the oxygen of samples in the field, to express results unit (mg L-1) according to APHA (2005).

$$\text{DO (mg L}^{-1}\text{)} = \frac{V_{\text{Na2S2O3}} \times N_{\text{Na2S2O3}} \times 200}{V \text{ sample}}$$

Chlorides (Cl^-)

Samples of 50 mL in volume were taken in conical flask, followed by adding 2-3 drops of potassium dichromate solution. It was titrated with 0.025N AgNO3 till the color changed from yellow to brick red, then reading was performed from the burette and the results were expressed as mg L-1 according to APHA (2005).

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$$\text{Cl (mg L}^{-1}\text{)} = \frac{V_{AgNO3} \times N_{AgNO3} \times 1000 \times \text{Mole} - \text{wt}_{\text{as AgNO3}}}{\text{V sample}}$$

Sulphate (SO_4^{-2})
Sulfate ions were determined using the spectrophotometer method. Water samples (100 mL) was taken. Thereafter, 5 mL of the conditioned solution was added and the condition reagent was shaken mechanically at a constant speed using a magnetic stirrer with Hot plate (AKI, Germany). Then, the barium chloride crystals were added with continued mechanical shaking for 1 minute, and examined with the UV-Spectrophotometer (Germany) at wavelength of 420 nm. Thereafter, the concentrations were read and calculations were made against the standard curve. The results were expressed as mg L^{-1} (APHA 2005).

Nitrate (NO_3^-)
Nitrate was measured using a Cadmium column method depending on the method published by Strickland & Parsons (1972). The samples were passed through cadmium column after getting rid of 25 mL at the beginning of the scroll. The rest of the sample was collected followed by adding the first reagent, i.e., Sulphanilamide and placing it in the dark for 4-6 min. Then a second reagent, i.e., N-1-naphthylenediamine dihydro Chloride was added and after 10 min, absorbance was measured in the device spectrophotometer (CE 1011CECIL) at a wavelength of 543 nm and the results were expressed as µg of nitrogen atom per liter.

$NO_{3\text{ as}}$ µg L^{-1} = ABS × F
Phosphate PO_4^{-2}

Phosphates were measured according to Strickland & Parsons (1972). The 100 mL-samples were taken, followed by directly adding 10 mL of the mixed solution prepared to these samples. The intensity of the blue color is proportional to the phosphate concentration. The samples were read after 2-h passing through a spectrophotometer CE 1011CECIL at a wavelength of 885 nm. The results were expressed as µg of phosphorous atom per liter.

PO_4 = ABS x F
Heavy metals

Heavy metals were measured according to APHA (2005). All samples were digested with Nitric acid (HNO_3) digestion. The analysis of cadmium (Cd^{+2}), lead (Pb^{+2}), manganese (Mn^{+2}) and zinc (Zn^{+2}) were conducted using atomic absorption spectrophotometer AAS6300 (Japan) and expressed as mg L^{-1}.

CCME-WQI calculation
The CCE-WQ index was determined using nine parameters as shown in Table 2 based on the following steps (CCME 2001):

1- **F_1 (Scope)**

$$F1 = \left[\frac{Number\ of\ failed\ variables}{Total\ number\ of\ variables}\right] \times 100$$

2- **F2 (Frequency)**

$$F2 = \left[\frac{Number\ of\ failed\ tests}{Total\ number\ of\ variables}\right] \times 100$$

3- **F3 (Amplitude)**

$$F3 = \left[\frac{nse}{0.01\ nse + 0.01}\right]$$

$$nse = \left[\frac{\sum_{i=1}^{n} Excursion}{Number\ of\ tests}\right]$$

whereas the test result might not be higher than the objective:

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$$Excursion\ i = \left[\frac{Failed\ test\ value\ i}{Objective\ j}\right] - 1$$

In cases where the tests result might not fall below the objective:

$$Excursion\ i = \left[\frac{Objective\ j}{Failed\ test\ value\ i}\right] - 1$$

The following formula can be used to calculate the CCME-WQI

$$WQI = \frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}$$

Table 2 shows the water surface state according to CCME-WQI.

Table 2. Categorization scheme of CCME WQI (CCME 2001).

Rating	WQI values	Statement
Excellent	95-100	Water quality is protected with a virtual absence of threat or impairment conditions, very close to natural or pristine levels.
Very Good	89-94	Water quality is protected with a slight presence of threat or impairment conditions, close to natural or pristine levels.
Good	80-88	Water quality is protected with only a minor degree of threat or impairment; conditions, rarely depart from natural or desirable levels.
Fair	65-79	Water quality is usually protected but occasionally threatened or impaired condition, sometimes depart from natural or desirable levels.
Marginal	45-64	Water quality is frequently threatened or impaired, conditions often depart from natural or desirable levels.
Poor	0-44	Water quality is almost always threatened or impaired, conditions usually Depart from natural or desirable levels.

STATISTICAL ANALYSIS

The SPSS 20.0 program was used to analyze the results by ANOVA test, this test shows the presence or absence of significant differences in the studied variables (physicochemical parameters).

RESULTS AND DISCUSSION

The results of the selected parameters during the study period in addition to the standard deviations, mean, and water quality index are shown in Table 3. The WQI values are shown graphically in Fig. 2. The CCME-WQI values ranged from 56 to 62 and therefore can be categorized as marginal in all studied sites, which may be due to exceeding most parameters involved in the calculation of the water quality index at the desirable levels. This indicates that the water quality of Tigris River deteriorates from the upper (Al-Aziziyah zone) to the lower (Kut dam). This results is consistent with those of Al-Janabi *et al*. (2015) who reported that CCME-WQI values in Tigris River ranged between poor to marginal, while is inconsistent with most of other studies (Al-Janabi *et al.* 2012; Darweeh 2017; Farhan *et al.* 2020).

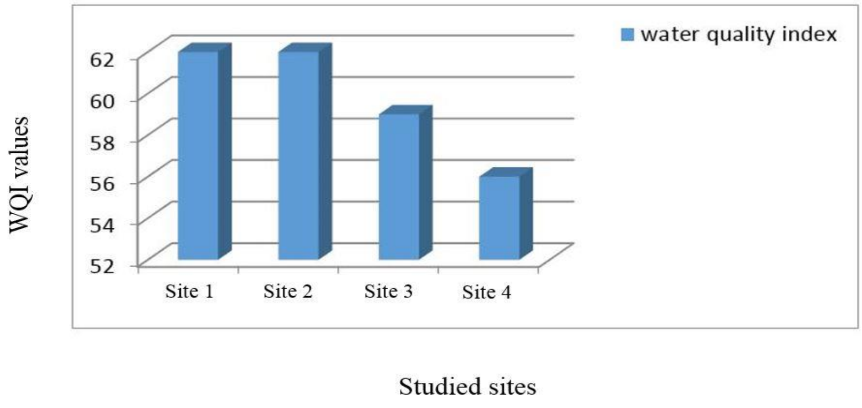

Fig. 2. Water quality index for drinking purposes along Tigris River.

Table 3. Test results for chemical and physical parameters (mean & standard deviation) throughout the study period (ND = not valid).

Parameters / Sites	**pH**	**Cl^{-1} (mg L^{-1})**	**DO (mg L^{-1})**	**NO_3^- (mg L^{-1})**	**PO_4^{-2} (mg L^{-1})**	**SO_4^{-2} (mg L^{-1})**	**Zn^{+2} (mg L^{-1})**	**Mn^{+2} (mg L^{-1})**	**Pb^{+2} (mg L^{-1})**
1	6.9-8.2 7.275 ± 0.399	71-131.4 96.74 ± 25.85	5.30-11.6 8.32 ± 2.29	0.671-25.69 19.21 ± 7.963	0.026-0.989 0.711 ± 0.366	100.3-232.5 153.2 ± 67.91	0.001-0.036 0.118 ± 0.011	0.042-0.21 0.162 ± 0.184	ND-0.33 0.140 ± 0.112
2	6.7-8.2 7.185 ± 0.351	78.1-134.9 98.35 ± 26.71	6-11.8 8.41 ± 2.223	0.635-25.98 15.82 ± 7.054	0.052-0.910 0.534 ± 0.324	103.4-211.3 154.8 ± 68.45	ND-0.062 0.028 ± 0.022	0.160-0.264 0.198 ± 0.031	ND-0.440 0.235 ± 0.121
3	6.9-8.3 7.30 ± 0.488	71-127 100.1 ± 33.35	6.2-12 8.498 ± 2.289	0.660-27.04 16.52 ± 7.833	0.052-0.92 0.542 ± 0.337	110.5-300 161.1 ± 69.61	0.003-0.025 0.025 ± 0.092	0.041-0.303 0.210 ± 0.189	ND-0.355 0.219 ± 0.123
4	6.4-7.9 7.241 ± 0.445	74.55-134.9 99.84 ± 32.10	7.2-12.2 8.650 ± 2.332	0.803-27.84 16.32 ± 8.014	0.078-0.962 0.559 ± 375	116.5-180.2 150.7 ± 65.23	0.005-0.031 0.018 ± 0.025	0.053-0.227 0.172 ± 0.069	0.001-0.412 0.292 ± 0.125
Objective	**6.5-8.5**	**200**	**>5**	**15**	**0.4**	**200**	**0.5**	**0.1**	**0.05**

The variables consistently exceed standards included PO_4^{-3}, NO_3^-, SO_4^{-2} Pb^{+2}, Mn^{+2}, while pH, DO, Cl^-, and Zn^{+2} were within the standard ranges. It was noticed during the study period that the pH values in the Tigris River tended to be basal as they ranged from 6.4 to 8.3. This result is consistent with those of other authors (Al-Jeboory 2005; Hassan *et al.* 2014; Salman *et al*. 2015; Hanna *et al*. 2019) who reported that surface water in Iraq is ranged from neutral to sub-alkaline in nature. Al-Ridah *et al.* (2020) showed that the CCME-WQI method categorized the river water as fair and treated water as good for drinking water due to suffering from water pollution and high human consumption of water. DO values ranged from 5.3 mg L^{-1} at Site 1 to 12.2 mg L^{-1} at Site 4. DO values were within the Iraqi standards for Maintenance of rivers from pollution. This results are in agreement with other studies (Al-Jananbi 2015; Ali *et al*. 2017; Ali *et al*. 2019), while are in disagreement with those of Farhan et al. (2020). Chlorides were within the permissible limits (350 mg L^{-1}) throughout the study period.

These values were inconsistent with the results of Darweeh (2017), Al-Ridah *et al.* (2020) and Chabuk *et al.* (2020). The higher concentrations of nitrate exceeded the permissible limits of Iraqi standards in the various sites which is a sign of degradation in the quality of the water and leading to eutrophication. Excessive concentration of nitrates may be due to domestic sewage and other anthropogenic activities as well as the soil corrosion and excessive use of fertilizers, since the adjacent areas are agricultural land (Shraddha *et al.* 2011). These high values of NO3 are consistent with almost all studies (Al-Janabi 2015; Ali *et al*. 2017; Ali *et al*. 2019).

The results showed that the phosphate was exceeding the permissible limits of Iraqi standards. Phosphorus concentrations revealed a significant increase which is might be due to the agricultural nature of the catchment and the anthropogenic activities (Sharpley 2005). The higher values of sulfate were exceeded the permissible limits in all the studied sites except Site 4, in disagreement with those reported by Chabuk *et al.* (2010). In addition, heavy metals (lead and manganese) throughout the study period exceeded the limits of Iraqi standards, whereas zinc concentration was within the permissible limits except at Site 2 which exceeded the limits. The erosion of metamorphic and igneous rocks is the main natural source of heavy metals. On the other side, extensive use of fertilizers (Darweesh 2017) and waste water resulting from car wash beside the studies sites can be considered as the most important artificial sources of heavy metals (Al-Janabi 2011).

CONCLUSIONS

This study revealed that the river is not suitable for drinking water supply. The source of pollution needs to be controlled and the water needs to be treated before use. In addition, the CCME gave reasonable results and reflect the variation of the river WQ parameters.

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Authors' Contribution

Shaimaa Fatih performed experimental part and wrote the manuscript draft and prepared the final version of the paper. Reidh Abas proposed the research idea. Helal Hamud helped the writing up.

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